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DEVICE AND SYSTEM FOR PRESSURE SENSING AND CONTROL

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DEVICE AND SYSTEM FOR PRESSURE SENSING AND CONTROL

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates generally to systems for pressure monitoring and control. More particularly, the present invention relates to a gauge with integrated pressure control capability.

BACKGROUND OF THE INVENTION

[0002] Many of the processes used to manufacture computer chips or integrated circuits take place at a controlled pressure that is less than atmospheric pressure. If the pressure changes, even by a small amount, the properties of the circuits being worked upon can change. This can produce an unusable batch of circuits. Therefore, to ensure batch quality, pressure levels in the process chamber must be controlled with a reasonable degree of accuracy. Typically, the pressure is continuously controlled through a feedback control loop process. One of the most common systems to control pressure utilized by the semiconductor manufacturing industry is illustrated in FIGURE 1.

[0003] Figure 1 is a diagrammatic representation of a portion of typical prior art semiconductor manufacturing system 20. System 20 includes a process chamber 22 in which semiconductor components are fabricated, a gauge 24 to measure the pressure in process chamber 22, and a vacuum pressure controller 26 to compare the measured pressure from gauge 24 with a system set point. System 20 can also include a throttle valve 28 (e.g., a throttling gate valve, a poppet valve, a butterfly valve or other valve known in the art) attached to a vacuum pump (not shown) to regulate a flow of gas out of process chamber 22. Valve 28 can be throttled by valve drive 30 in response to control signals from vacuum pressure controller 26.

[0004] In operation, process chamber 22 can receive a flow of gas necessary for the manufacturing process (e.g., gas flow 32). The gas constituting gas flow 32 can depend on the particular manufacturing process being carried out in process chamber 22. As already noted, in order to ensure the quality of semiconductors and semiconductor components produced in process chamber 22 the gas pressure within process chamber 22 must be accurately controlled. This can be achieved by throttling valve 28 to regulate the flow of gas out of process chamber 22. To appropriately throttle valve 28, gauge 24 can read the pressure in process chamber 22 and send a signal (e.g., pressure signal 34) representing the pressure in process chamber 22 to a separate vacuum pressure controller 26. Pressure controller 26 can compare pressure signal 34 to a system set point (e.g., represented by set point signal 36) based on internal hardware and/or software algorithms which are well-known in the art. Set point signal 36 is typically provided by a control computer (not shown) which governs the entire manufacturing process. If pressure signal 34 varies from set point signal 36 according to pressure vacuum controller 26's internal algorithms, pressure vacuum controller 26 can generate control signal 38. Valve drive 30 can receive control signal 38 and throttle valve 28 appropriately. By adjusting valve 28, the net speed of an output flow 39 from process chamber 22 can be changed, thereby regulating the pressure in process chamber 22. Pressure

is typically not regulated, however, by changing the pumping characteristics of downstream vacuum pumps.

[0005] System 20 of Figure 1 typically has several shortcomings. Because pressure vacuum controller 26, gauge 24 and valve drive 30 are separate units, a significant number of cables are required. Due to the increased number of cables there is a greater chance a signal will encounter interference from the power cable or power source. Additionally, the large number of cables required for system 20 can be exceedingly expensive and can require a significant amount of setup time

[0006] To overcome several of these deficiencies additional systems have been developed. Figure 2 illustrates a semiconductor manufacturing system 40 in which pressure vacuum controller 26 and valve drive 28 are combined. System 40 includes a process chamber 22 in which semiconductor components are fabricated the gauge 24 to measure the pressure in process chamber 22 and a combined pressure vacuum controller 26 and valve drive 30 (e.g., unit 42). Unit 42 can govern valve 28 to regulate the pressure in process chamber 22. Again, gauge 24 can read the pressure in process chamber 22 and send a signal (e.g., pressure signal 34) representing the pressure in process chamber 22 the unit 42. The pressure vacuum controller 26 and unit 42 can compare pressure signal 34 with them with a set point signal 36. Based on the comparison of set point signal 36 to pressure signal 34, pressure vacuum controller 26 can generate control signal

38 to control valve drive 30. Valve drive 30 can throttle valve 28 according to the control signal, thereby regulating the pressure in process chamber 22. Because pressure vacuum controller 26 and valve drive 30 are combined in unit 42, the number of cables required relative to system 20 is reduced, thereby decreasing costs and the probability that interference in a signal cable can occur. Additionally, by combining devices, physical space is saved, though valve drive 30 with vacuum pressure control 26 (e.g., unit 42) is larger than valve drive 30 alone.

[0007] However, system 40 also suffers from several deficiencies. A major deficiency for system 40 is that valve 28 can vibrate, sometimes significantly, causing noise in signals produced by vacuum pressure controller 26. The vibrations can emanate from several sources including the downstream vacuum pumps or valve drive 30. The signal noise created by the vibrations can lead to a reduction in accuracy. Additionally, because valve drive 30 generally utilizes a high-voltage DC motor to throttle valve 28, pressure vacuum controller 26 can experience significant interference that can reduce the accuracy of overall pressure control. Thus, although interference due to extensive cabling is reduced, overall interference can increase.

[0008] A further disadvantage of system 40 is that valve 28 and valve drive 30 are usually difficult to maintain and replace. Because pressure vacuum controller 26 is

combined with valve drive 30, pressure vacuum controller 26 is, consequently, also difficult to maintain or replace. If there is a fault in pressure vacuum controller 26, system 40 may have to be shut down for a significant period of time, leading to potentially millions of dollars in lost profit.

SUMMARY OF THE INVENTION

[0009] Embodiments of the present invention provide devices that reduce or eliminate the disadvantages associated with prior art pressure control devices and systems. More particularly, embodiments of the present invention provide devices and systems in which pressure sensing and pressure control capabilities are integrated.

[0010] One embodiment of the present invention can include a device for pressure sensing and control comprising a sensor portion and a control portion. The sensor portion can be operable to sense a pressure and the control portion can be operable to compare the sensed pressure to a set point, generate a control signal based on a difference between the sensed pressure and the set point, and output the control signal. The sensor portion and the control sensor portion and control portion can be integrated in a housing.

[0011] Another embodiment of the present invention can include a system for pressure control comprising a process chamber, a valve in fluid communication with the process chamber, a valve drive responsive to a control signal to open and close the valve and a gauge with integrated pressure control coupled to the process chamber. The gauge with integrated pressure control can comprise a sensor portion at least partially exposed to a fluid in the process chamber operable to sense a pressure in the process chamber and a control portion operable to compare a sensed pressure to a set point, generate the control

signal based on a difference between the sensed pressure and the set point, and output the control signal. The control portion and sensor portion can be integrated in a housing.

[0012] Yet another embodiment of the present invention can include a gauge with integrated pressure control. The gauge can comprise a pressure sensor to output a sensed pressure, a processor coupled to the pressure sensor, and a memory accessible by the processor storing software executable by the processor. The software instructions can comprise instructions executable to receive the sensed pressure, compare the sensed pressure to a set point, and generate a control signal based on a difference between the sensed pressure and the set point.

[0013] The present invention provides technical advantages over prior art process control systems by reducing signal interference. Because the pressure controller is integrated with a gauge, there are fewer cables in which interference can occur. Additionally, because the pressure controller is not located at a valve drive, the pressure controller will receive less or no interference from the valve drive motor.

[0014] The present invention provides another technical advantage by reducing process chamber downtime. Downtime can be decreased because the gauge with the integrated pressure control capability can easily be switched out or replaced.

[0015] The present invention provides yet another important technical advantage by reducing cabling. By reducing cabling, the costs associated with cabling are also reduced.

[0016] The present invention provides yet another important technical advantage by saving space.

[0017] The present invention provides yet another important technical advantage by reducing the effects of system vibration on the pressure controller, thereby increasing reliability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] A more complete understanding of the present invention and the advantages thereof may be acquired by referring to the following description, taken in conjunction with the accompanying drawings in which like reference numbers indicate like features and wherein:

[0019] FIGURE 1 illustrates a prior art system for process control in semiconductor manufacturing;

[0020] FIGURE 2 illustrates another prior art system for process control in semiconductor manufacturing;

[0021] FIGURE 3 is a diagrammatic representation of a system for pressure sensing and control implementing a gauge with integrated pressure control capability according to the teachings of the present invention;

[0022] FIGURE 4 is a diagrammatic representation of one embodiment of a pressure gauge with integrated pressure control capability according to the present invention; and

[0023] FIGURE 5 is a flow chart illustrating one embodiment of a method for generating a control signal.

DETAILED DESCRIPTION OF THE INVENTION

[0024] Preferred embodiments of the present invention are illustrated in the FIGUREs, like numerals being used to refer to like and corresponding parts of the various drawings.

[0025] Pressure controllers are commonly used in semiconductor manufacturing as part of a control process to govern gas pressure within a process chamber. A pressure gauge can read the gas pressure within the process chamber and a pressure controller can compare the detected or measured pressure with a set point. A difference between the detected pressure and the set point can cause the pressure controller to generate an electric signal to open or close a valve, thereby controlling chamber pressure. Embodiments of the present invention provide a pressure gauge with integrated pressure control capability. Because pressure gauges according to the teachings of the present invention include integrated pressure control capability, the need for a separate pressure controller is eliminated.

[0026] FIGURE 3 illustrates a semiconductor manufacturing system 50 that includes a process chamber 52, a pressure gauge with integrated pressure control capability 54 ("pressure gauge 54"), a throttle valve 56, and a valve drive 58. Valve 56 can be a throttling gate valve, a poppet valve, a butterfly valve or any other valve known in the art. In system 50, process chamber 52 can receive a flow of fluid (e.g., gas flow 60), typically, from a mass flow

controller (not shown). The fluid constituting gas flow 60 can depend on the particular manufacturing process being carried out in process chamber 52 and can include gas vapor mixes. Pressure gauge 54 can read the pressure in process chamber 52 and compare the sensed pressure with a set point. The set point can be provided by way of a digital or analog set point signal 62 from a control computer which monitors the overall system process or by another device not shown) or other device. In another embodiment of the present invention a set point value can be stored at gauge 54.

[0027] If there is a difference between the sensed pressure and the set point, pressure gauge 54 can generate a control signal (e.g., signal 64) and can communicate the control signal to valve drive 58. As most current valve drive systems operate on analog signals, control signal 64 can be in analog form. However, as would be understood by one of ordinary skill in the art, control signal 64 can, in other embodiments of the present invention, be a digital signal. Based on control signal 64, valve drive 58 can throttle valve 56 to regulate the net speed of gas flow out of pressure chamber 52 (e.g., output gas flow 66). By regulating the speed of a downstream flow, the pressure in an upstream chamber can be controlled. Thus, by throttling valve 56, the pressure in process chamber 52 is controlled. The pressure can be maintained in a sub-atmospheric (e.g., vacuum) state, at atmospheric pressure or above atmospheric pressure.

[0028] FIGURE 4 is a diagrammatic representation of one embodiment of pressure gauge 54 with integrated pressure control. Pressure gauge 54, according to one embodiment of the present invention, can include a sensor portion 68 and a control portion 69. Control portion 69, in this embodiment of the present invention, can include an analog to digital converter (A-to-D converter) 70, a digital signal processor (DSP) 72 and a memory 74 (e.g., RAM, ROM, EEPROM, Flash memory, magnetic storage device or other memory known in the art) accessible by DSP 72. Memory 74 can store software instructions 76 for generating a control signal based on the pressure sensed by sensor portion 68. Gauge 54 can include various input/output capabilities. For example, gauge 54 can include a serial interface to support administrative functions such as updating computer instructions 76. Additionally, gauge 54 can include network interfaces to communicate with other flow control devices, administrative computers or other device capable of communicating over a network. In one embodiment of the present invention, sensor portion 68 and control portion 69 can be integrated in a housing 78. Housing 78 can be configured to mount to or in a process chamber (e.g., process chamber 52 of FIGURE 3) according to any scheme known in the art. Gauge 54 can be configured such that sensor portion 68 can be at least partially exposed to the fluid in the process chamber to read the pressure in the process chamber.

[0029] Sensor portion 68 can include mechanical and/or electrical components associated with a pressure sensor. As an example, sensor portion 68 can include a diaphragm capacitance sensor. Typically, in a diaphragm capacitance sensor, there is a thin metal or ceramic diaphragm that is exposed on one side to the process gas (e.g., the gas in process chamber 52 of FIGURE 3). On the other side of the diaphragm, there is typically a vacuum. The metal diaphragm is usually on the order of 1/1000-inch thick or less, depending on the characteristics of the particular capacitance diaphragm sensor. As the pressure in process chamber 52 increases, the amount of deflection in the metal diaphragm changes. This can cause the capacitance between the diaphragm and another metal plate or electrode to change. A circuit connected to the diaphragm and metal plate can output an analog sensor voltage that is influenced by the capacitance between the diaphragm and metal plate. Thus, sensor portion 68 can output a sensed pressure signal corresponding to the pressure in the process chamber. Other example sensors include, but are not limited to, pirani sensors, hot cathode sensors, cold cathode sensors, thermocouple based sensors or any other pressure sensor known in the art.

[0030] According to one embodiment of the present invention, sensor portion 68 can output the sensed pressure signal as an analog signal. A-to-D converter 70 can convert the analog sensed pressure signal to a digital pressure signal and forward the digital pressure signal to DSP 72.

Additionally, A-to-D converter 70 can receive an analog set point signal and convert the analog set point signal to a digital set point signal. In another embodiment of the present invention, the set point can be received as a digital set point signal or can be stored in memory (e.g., memory 74) as a set point value. DSP 72 can execute instructions 76 to compare the sensed pressure to the set point and generate a digital control signal accordingly. A-to-D converter 70 can convert the digital control signal to an analog control signal and forward the analog control signal to a valve drive (e.g., valve drive 58 of FIGURE 3). In another embodiment of the present invention, gauge 54 can send a digital control signal to the valve drive.

[0031] Thus, control portion 69 can provide pressure control functions. DSP 72 can process software instructions stored in memory 74 to apply various algorithms to compare the sensed pressure with a set point. If a difference between the measured pressure and the set point is detected when pressure gauge 54 compares the measured pressure to the set point, the pressure gauge can generate a control signal. A valve drive can be responsive to the control signal to open or close an associated valve, thereby regulating pressure in the process chamber.

[0032] Control portion 69 can also implement self-diagnostics. For, example, if sensor portion 68 is a diaphragm capacitance sensor, DSP 72 can execute software

instructions 76 to determine if the capacitance or sensed pressure exceeds or goes outside of predetermined bounds (e.g. goes outside performance parameters) and, if so, generate an alarm. Additionally, DSP 72 can monitor the temperature in the sensor and if the temperature goes out of predefined bounds, can trigger an alarm. In this case, the alarm can be generated at gauge 54 rather than at a separate tool.

[0033] It should be noted that the embodiment of FIGURE 4 is provided by way of example only and the sensor portion and control portions of the gauge can comprise various components for sensing a pressure and generating a control signal in response to the sensed pressure. The control portion and sensor portion can include shared and/or separate components. The sensed pressure can be communicated from the sensor portion to the control portion as an analog signal, a digital signal or in any other manner known in the art.

[0034] FIGURE 5 is a flow chart illustrating one embodiment of a method for pressure control according to the present invention. At step 100, a gauge with integrated pressure control (e.g., pressure gauge 54 of FIGURE 3 and FIGURE 4) can measure a pressure. The pressure can be assessed using any pressure measurements scheme known in the art. The gauge with integrated pressure control, at step 102, can compare the sensed pressure to set point 104. If there is a difference between the sensed pressure and the set point, as determined at step 106,

the gauge can generate an error signal. At step 108, the gauge with integrated pressure control can generate a control signal based on the difference between the sensed pressure and the set point.

[0035] In one embodiment of the present invention, the gauge can generate the control signal by executing a computer program that can include a control algorithm, stored as a set of computer instructions on a computer readable memory (e.g., EEPROM, RAM, ROM, flash memory, magnetic storage, optical storage or other computer readable memory known in the art). The control algorithm can calculate the digital control signal using any control scheme known in the art, including, but not limited to a proportional-integral ("PI") control scheme, a proportional-integral-derivative ("PID") control scheme, a modified PID with offset or other control algorithm known in the art. The control signal can be communicated to a valve drive (step 110) in digital or analog format. These steps can be continually repeated (step 112) to monitor and control pressure over time.

[0036] The present invention provides advantages over prior art pressure monitoring and control systems. Because the process chamber is typically isolated from vibrations, a gauge with integrated pressure control capability will experience significantly less vibration than a valve drive with pressure control capability and, consequently, will experience less vibration induced noise. Additionally, a vacuum gauge with pressure control

capability will experience less interference from the high voltage DC motor in the valve drive than a pressure controller located at the valve drive because the gauge with integrated pressure control can be located away from the valve drive.

[0037] Furthermore, the present invention offers advantages with respect to ease of pressure controller replacement and repair in comparison to pressure controllers integrated at the valve drive. To replace or maintain a valve drive, an operator must shut down the semiconductor manufacturing system, evacuate any poisonous or corrosive gases from the system, and then access the typically cumbersome and inconveniently located valve drive. Thus, replacing valve drive can require substantial amounts of time. Gauges, on the other hand, are generally removably attached to the process chamber and are easy to remove and replace, decreasing the amount of downtime required if the pressure controller experiences inaccuracy or other difficulties.

[0038] While the present invention has been described in terms of integrating pressure control capability primarily with a capacitance diaphragm gauge, the pressure controller can be integrated with other forms of gauges. While various gauges, including parini gauges, thermocouple gauges, cold cathode gauges, and hot cathode gauges, typically do not include significant on-board electronics, pressure control circuitry can be added in the same physical housing. In gauges such as cold

cathode gauges that typically use very high voltages, shielding can be used to separate pressure control components from the sensor portion while remaining integrated in the same physical housing. Moreover, while the gauge with integrated pressure control has been described primarily in terms of a gauge used to sense and control pressure in a process chamber, embodiments of the present invention are suitable for a variety of applications requiring pressure sensing and control.

[0039] Although the present invention has been described in detail herein with reference to the illustrative embodiments, it should be understood that the description is by way of example only and is not to be construed in a limiting sense. It is to be further understood, therefore, that numerous changes in the details of the embodiments of this invention and additional embodiments of this invention will be apparent to, and may be made by, persons of ordinary skill in the art having reference to this description. It is contemplated that all such changes and additional embodiments are within the spirit and true scope of this invention as claimed below.